

REMARKS/ARGUMENTS

Claim 2 was rejected under 35 U.S.C. §112, paragraph 2, on the ground that in the Examiner's opinion, the current mirror was part of the comparator and therefore it was improper to recite the current mirror and the comparator as separate elements in claim 2.

The rejection is respectfully traversed. As shown in Fig. 6, the current mirror circuit comprises two bipolar transistors (not numbered) and two current sources I and NI see Fig. 2 and page 1, lines 15-21). On the other hand, the comparator is made up of FETs Q2, Q3 and Q4 (see page 5, lines 1-10).

Therefore, the current mirror and the comparator are separate elements and can be claimed as such.

Since claim 2 was not rejected over any prior art, allowance of claim 2 is requested.

Claims 1 and 3 were rejected as being anticipated by Fischer. Claim 1 is being canceled, and claim 3 is being amended to recite, in part, a combination of a first bipolar transistor providing V_{be} , two additional bipolar transistors in a current mirror circuit providing ΔV_{be} , a comparator that receives V_{be} and ΔV_{be} , and other features. No such combination is seen in the art. Allowance is therefore requested.

THIS CORRESPONDENCE IS BEING
SUBMITTED ELECTRONICALLY
THROUGH THE PATENT AND
TRADEMARK OFFICE EFS FILING
SYSTEM ON July 25, 2006.

JAF:lf

Respectfully submitted,



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TEMPERATURE COMPENSATED BANDGAP VOLTAGE REFERENCECROSS REFERENCE TO RELATED APPLICATIONS

This application is based on and claims priority of U.S. provisional patent application Serial No. 60/441,063, filed January 17, 2003, entitled TEMPERATURE
5 COMPENSATED BANDGAP VOLTAGE REFERENCE, the entire disclosure of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

The present invention is directed to a temperature compensated bandgap voltage reference.

10 Figure 1 shows how a reference voltage based upon V_{be} of a bipolar transistor can be obtained. The current source I is provided in the emitter path of a bipolar transistor. A plurality of current sources can be provided each coupled to an FET of varying size to provide current sources of different magnitude, e.g., I , $10I$, etc. as shown.

15 V_{be} of a bipolar transistor decreases with increasing temperature in a well-known fashion. See Fig. 3. It is also known that a current mirror can be used to obtain a voltage representative of proportional to ΔV_{be} i.e., the difference between the V_{be} of two bipolar transistors. Figure 2 shows such a current mirror circuit. ΔV_{be} is equal to V_{be2} minus V_{be1} and ΔV_{be} is equal to $kt/q \ln NI/I$. ΔV_{be} depends upon the
20 ratio of the currents of the current sources as well as the temperature. In particular, ΔV_{be} increases with temperature. See Fig. 3. By combining the two circuits, it is possible to compensate V_{be} of a first transistor with ΔV_{be} obtained via two other transistors Q1 and Q2, to obtain a substantially constant reference voltage V_{ref} as

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shown in Fig. 3. In particular, V_{ref} is equal to a constant A times V_{be} plus a constant B times ΔV_{be} .

SUMMARY OF THE INVENTION

The invention provides a new implementation of a V_{be}
5 bandgap voltage reference that sums V_{be} and ΔV_{be} to obtain a substantially constant temperature independent voltage reference. The circuit uses a current mirror for ΔV_{be} and a bipolar transistor to provide V_{be} . A comparator is implemented as a differential amplifier and receives inputs proportional to V_{be} and ΔV_{be} . The output of the comparator is coupled back to the input of the bipolar transistor that provides
10 V_{be} .

According to one aspect, the invention comprises a bandgap voltage reference circuit comprising a first circuit providing a first voltage representative of
~~substantially proportional to~~ V_{be} of a first bipolar transistor, a second circuit providing a second voltage ΔV_{be} representative of ~~substantially proportional to~~ the
15 difference of two V_{be} voltages of two bipolar transistors; and a comparator having respective inputs which receive voltages representative of ~~coupled to~~ V_{be} and ΔV_{be} and an output coupled to the base of the first bipolar transistor whereby a voltage representative of ~~substantially proportional to~~ the sum of respective constants multiplying V_{be} and ΔV_{be} is provided at the output of the comparator.

20 According to another aspect, the invention comprises a bandgap voltage reference circuit comprising a first bipolar transistor providing substantially a reference voltage V_{be} , a current mirror circuit comprising two bipolar transistors coupled in a current mirror arrangement for providing a voltage difference ΔV_{be} comprising substantially a difference signal between the respective V_{be} voltages of
25 the two bipolar transistors; and a comparator having respective inputs which receive voltages representative of ~~coupled to~~ V_{be} and ΔV_{be} and an output coupled to the base of the first bipolar transistor whereby a voltage representative of ~~substantially~~

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proportional to the sum of respective constants multiplying V_{be} and ΔV_{be} is provided at the output of the comparator.

According to yet another aspect, the invention comprises a bandgap voltage reference circuit comprising a first circuit providing a first voltage representative of substantially proportional to V_{be} of a first bipolar transistor, a second circuit providing a second voltage ΔV_{be} representative of substantially proportional to the difference of two V_{be} voltages of two bipolar transistors, and a comparator having respective inputs which receive voltages representative of coupled to V_{be} and ΔV_{be} and an output coupled to the base of the first bipolar transistor whereby a substantially temperature independent voltage reference is provided at the output of the comparator.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a prior art circuit for generating a reference voltage based on V_{be} of a bipolar transistor;

Fig. 2 shows a prior art circuit mirror circuit for generating a voltage proportional to ΔV_{be} ;

Fig. 3 is a graph showing the relationship of V_{be} and ΔV_{be} and a reference voltage comprising weighted sums of V_{be} and ΔV_{be} ;

Fig. 4 shows the reference voltage generating circuit according to the invention;

Fig. 5A and 5B shows waveforms of the circuit of Fig. 4; and

Fig. 6 shows a schematic diagram of an implementation of the circuit of the invention.

DETAILED DESCRIPTION OF THE INVENTION

According to the invention, a new implementation for deriving the voltage bandgap reference V_{ref} is provided. As shown in Fig.4, a bipolar transistor Q1

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provides V_{be} . The emitter of the bipolar transistor Q1 is coupled to a resistor divider comprising resistors R1 and R2. The output of the divider is provided to a comparator UI inverting input. The non-inverting input of the comparator UI is provided to the voltage source comprising ΔV_{be} , which may be generated by the circuit of Fig. 2. The output of the comparator is provided back to the input IN'.

This results in the following equations:

$$IN- = (IN' - V_{be})x \frac{R_2}{R_1 + R_2}$$

$$\Delta V_{be} = (IN'_{\Delta V_{be}} - V_{be})x \frac{R_2}{R_1 + R_2}$$

$$IN' = OUT$$

$$OUT = IN'_{\Delta V_{be}} \text{ (from Fig. 5B)}$$

$$IN'_{\Delta V_{be}} = V_{be} + \frac{R_1 + R_2}{R_2} \Delta V_{be}$$

$$IN'_{\Delta V_{be}} = OUT = V_{be} + \frac{R_1 + R_2}{R_{[1]}^2} \Delta V_{be}$$

The output of the comparator is shown in Figs. 5A and 5B versus IN- and IN', respectively. Figure 5A shows the output versus IN- i.e., versus the input at the inverting input of the comparator. Figure 5B shows the output versus IN', i.e., versus the input to the transistor Q1 providing the V_{be} reference voltage. Since the output of the comparator is coupled to the input IN', the output equals $V_{be} + (R_1 + R_2)/R_1 \Delta V_{be}$. Accordingly, the output voltage is a constant voltage equal to V_{be} plus a constant times ΔV_{be} . With the appropriate selection of resistors R1 and R2, the output can remain constant.

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Figure 6 shows a complete circuit implementation where a current mirror circuit has been substituted for ΔV_{be} in Fig. 4. In addition, the comparator has been implemented by FETs Q2, Q3 and Q4 serving as a differential amplifier. The inputs IN- and IN+ are provided respectively at the sources of transistors Q2 and Q3 and the output OUT = V_{REF} is provided at the source of transistor Q4. ΔV_{be} is provided by the current mirror across the gates of the transistors Q2 and Q3. In Fig. 6, a voltage divider comprising resistors R3 and R4 is provided.

$$V_{out'} = V_{out} \left(\frac{R_3 + R_4}{R_3} \right)$$

In this way, the circuit can generate a reference voltage $V_{out'}$ that is a multiple of V_{out} . This is important in applications where a 1.25V reference voltage is too low.

Although the present invention has been described in relation to particular embodiments thereof, many other variations and modifications and other uses will become apparent to those skilled in the art. Therefore, the present invention should be limited not by the specific disclosure herein, but only by the appended claims.

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IR-2281 (2-3807)

5 TEMPERATURE COMPENSATED BANDGAP VOLTAGE REFERENCE

ABSTRACT OF THE DISCLOSURE

10 A bandgap voltage reference circuit comprising a first circuit providing a first voltage ~~representative of substantially proportional~~ to V_{be} of a first bipolar transistor, a second circuit providing a second voltage ΔV_{be} ~~representative of substantially proportional~~ to the difference of two V_{be} voltages of two bipolar transistors, and a comparator having respective inputs receiving voltages representative of ~~coupled to~~ V_{be} and ΔV_{be} and an output coupled to the base of the first bipolar transistor whereby a voltage ~~representative of substantially proportional to~~ the sum of respective constants multiplying V_{be} and ΔV_{be} is provided at the output of the comparator.